Department of Energy
Washington, DC 20585

SAFETY EVALUATION REPORT
BUSS (R-1) CASK
DOCKET 93-33-9511

SUMMARY

By application dated October 29, 1993, as revised, the United States Department of Energy (DOE) Albuquerque Operations Office requested a revised DOE Certificate of Compliance (CoC) for the BUSS (R-1) cask design. The DOE is the owner of the packaging design.

Based on the statements and representation made in the Safety Analysis Report for Packaging (SARP), Revision 4 (Reference 1), and the conditions listed below, the staff of the Transportation and Packaging Safety Division, EH-332, has concluded that the BUSS (R-1) cask design meets the requirements of DOE Orders 1540.2 and 5480.3, 10 CFR Part 71, and 49 CFR Part 173.

REFERENCES

1. Beneficial Uses Shipping System Cask, BUSS, Safety Analysis Report for Packaging (SARP), Volumes I and II, Report SAND 83-0698 (TTC-0430), Revision 4, May 1993, Sandia National Laboratories, Albuquerque, NM 87185.

DRAWINGS

The packaging is constructed in accordance with Sandia National Laboratories Drawing Numbers S54774, Rev. C, Cask in Cradle, S52614, Rev. D, Personnel Barrier-Lower, S52615, Rev. D, Personnel Barrier-Upper, and attendant referenced drawings with revision dates of February 28, 1994 or earlier.

The general information and drawings presented in the reference were reviewed by the staff and found acceptable. The BUSS (R-1) cask packaging is adequately described by the Sandia National Laboratories drawings. The drawings provide information pertaining to materials of construction, component dimensions and tolerances, and the location and size of all weld joints. The drawings identify the weld joints to be nondestructively examined and the code or standard for the examination procedure.

1. General

The BUSS cask contents are Category I quantity as defined in DOE/DP-0049, "Packaging Review Guide for Reviewing Safety Analysis Reports for Packagings" and Nuclear Regulatory Commission (NRC) Regulatory Guide 7.11. The BUSS (R-1) cask does not, as designed, provide a containment boundary but only provides a confinement boundary for Special Form capsules. Since the only welds to the cask do not directly relate to providing adequate shielding, they are not subject to ASME Code rules for fabrication.

The BUSS Model R-1 cask is a Type B packaging for shipping highway route controlled quantities of nonfissile, radioactive Special Form strontium-90 fluoride and cesium-137 chloride, double-wall (Type 316L stainless steel, Hasteloy C and Type 316L stainless steel, Type 316L stainless steel) capsules. The total gross weight of the fully loaded package is 15,286 kg (33,700 lb). The cask is shipped exclusive use.

This SER only assesses the changes to the BUSS Model R-1 cask design and performance based on the statements and representations made in Revision 4 of the SARP. Based on the statements and representations made in the revised SARP, the staff has concluded that the changed BUSS cask Shipping Package design meets the requirements of DOE Orders 1540.2 and 5480.3, 10 CFR Part 71, and 49 CFR Part 173.

1.1 Description

The changes in Revision 4 of the SARP to the package design include an increased package gross weight, a welded permanent repair plug in the cask body at the upper port, a removable bore plug in the upper port, a redesign of the personnel barrier, larger handle hole diameters for the baskets, and a changed bolt insert material for the baskets.

The package weight was increased by 363 kg (800 lb) from 14,923 kg (32,900 lb) to 15,286 kg (33,700 lb). This weight change is due to a 318 kg (700 lb) weight increase in the transportation skid and a 45 kg (100 lb) increase in the weight of the contents. The transportation skid weight increase was due to changes to accommodate the new personnel barrier design. The contents weight increase is a result of obtaining more accurate data on the filling of the capsules.

A permanent repair plug was threaded and seal-welded into the cask body at the upper port to correct a machining error that damaged the sealing surface. This plug forms a new surface for the drain plug seal. A removable bore plug was also added to the upper port. The personnel barrier was redesigned to attach to the transportation skid rather than to the trailer bed. The new personnel barrier fits between the impact limiters and is designed with a fixed lower portion and a removable upper portion. The handle holes in the baskets were increased in diameter to allow a greater clearance as the cask heats up. The basket handle bolt inserts were changed to a material with improved elevated-temperature mechanical properties. All of the changes to the packaging were incorporated in the drawings and are discussed in the SARP.

1.2 Contents and Fissile Class

The cask carries Special Form capsules containing up to 6.5×10^5 Ci of strontium-90 fluoride or 8.5×10^5 Ci cesium-137 chloride. These materials are not fissile so no fissile class is assigned. The contents in Revision 4 of the SARP remain the same as Revision 3.

2. Structural Evaluation

2.1 Structural Design

The significant changes in Revision 4 of the SARP that affect the structural design or performance of the BUSS (R-1) cask consist of three items. (1) The BUSS cask support system has been redesigned to accommodate the direct attachment of the personnel barrier to the support skid rather than to the transport truck trailer bed. This change is depicted in Drawing Number S52606, Rev. C, provided with Revision 4 of the SARP. (2) The weight of the entire package has increased from 14,923 kg (32,900 lb) to 15,286 kg (33,700 lb). This 363 kg (800 lb), 2.4%, change consists of a 45 kg (100 lb) increase in the contents weight, previously reported as a maximum of 136 kg (300 lb) and now reported as 181 kg (400 lb), and a 318 kg (700 lb) increase in the skid structure that the cask is mounted on during shipment. Revision 4 of the SARP explains the weight increases and discusses the expected consequences on the analysis results covered in Chapter 2 of the SARP. (3) A "plug bar" is inserted into the BUSS cask body in an opening machined into the upper drain port. The purpose of this plug bar is to repair a machining error. The plug is held in place through a 5-12UN-3A thread with 271 to 339 N-m (200 to 250 ft-lb) of torque. In addition, a seal weld keeps the attachment from loosening up. The "plug bar" repair has been reviewed by the staff and found to be acceptable.

The other changes introduced in Revision 4 of the SARP are the addition of a bore plug to the upper (front) drain port and a redesign of the personnel barrier. The addition of the bore plug has little structural significance because the plug is trapped in place by other components. The impact forces that could be produced by an unattached plug are discussed in Section 2.7 of this report. The personnel barrier provides a shield against hand access to the cask body but has no structural significance.

The design criteria, presented in Section 2.1.2 of Revision 4 of the SARP are the same as in Revision 3. The analytical presentations in Chapter 2 of the SARP are based on the original 14,923 kg (32,900 lb) design weight. The consequence of the increase to 15,290 kg (33,700 lb) is addressed at the conclusion of Chapter 2 as is the increase in the contents weight, from 136 to 181 kg (300 to 400 lb). The weight of the personnel barrier design shown in Revision 4 remains the same as the weight of the design shown in Revision 3.

2.2 Weights and Centers of Gravity

The correct weights and location of the center of gravity are not given in this section of the SARP. The staff has calculated that the location of the center of gravity will be lower relative to the horizontal axis by about 2.5 cm (1 in) in 100 cm (40 in) which is not significant.

2.3 Mechanical Properties of Materials

Revision 4 of the SARP incorporates several material designation changes using nomenclature introduced since the original SARP was written. These changes have been reviewed by the staff and are acceptable. The physical materials and the material requirements have not changed.

2.4 General Standards for All Packages

The requirements of 10 CFR 71.43 are met for any changes in Revision 4 of the SARP in the same manner as Revision 3.

2.5 Lifting and Tiedown Standards

The lifting and tiedown calculations are affected by the change in package weight in a purely linear manner since stresses are required to remain elastic. Thus the 2.4% increase in package weight results in a 2.4% increase in stresses. In every component of the lifting and tiedown analysis, provided in the Appendix 2A of the SARP, a margin of more than 15% was shown to be available. Therefore, the increase in package weight is easily accommodated. The lowest available margin, about 16%, was for the stress in the trunnion fillet, with the cask subjected to forces equal to the package weight multiplied by the load factors specified in 10 CFR 71.45(b)(1), applied to the center of gravity of the package.

The tiedown design has not been changed in any manner that is significant to the calculation of stresses due to the tiedown loadings. Transverse dimensions of the skid have been increased to accommodate attachment of the personnel barrier. However, the dimensions of the crushable box supporting the cask, which is the significant component with respect to the behavior of the tiedown system, have not been changed.

2.6 Normal Conditions of Transport

For the normal conditions of transport, the forces associated with the drop tests and deformations associated with the temperature gradients do not change significantly as a result of the changes given in Revision 4 of the SARP. Margins of 100% or more are available to withstand the loads that would vary with the package weight. With these margins, the 2.4% change is not significant. Temperature gradient deformations remain unchanged and would be of concern only in evaluating containment boundary integrity which is not a requirement for the confinement boundary of the BUSS package.

2.7 Hypothetical Accident Conditions

With one exception, the 2.4% increase in package weight does not change any of the conclusions reached in Revision 3 of the SARP for the hypothetical accident 9 m (30 ft) drop conditions. The margins calculated in Revision 3 of the SARP exceed 2.4% and accommodate the package weight increase for all drop orientations. The exception is that, in the case of a side drop orientation, the crushing depth predicted in the SARP is 28.4 cm (11.2 in) (see Appendix 2D.4). This crushing depth occurs when the lowest foam density and highest ambient temperature foam mechanical properties are used in the calculations. The available crushing depth for a side drop, before the flat end of the lifting trunnion makes contact with the unyielding surface, is 28.7 cm (11.3 in). The 0.25 cm (0.1 in) margin theoretically available is not sufficient to accommodate a 2.4% package weight increase and still prevent impact to the trunnion. However, for the 363 kg (800 lb) increase in weight, the potential energy change for a 9 m (30 ft) drop is 33,000 N-m (24,000 ft-lb). Compare this energy change to the impact energy for a drop to a puncture bar from a 1 m (3.33 ft) height with direct impact of the bar by the 14,970 kg (33,000 lb) cask, which is 149,000 N-m (110,000 ft-lb). The entire energy that remains to be dissipated at the instant of contact of the trunnion with the rigid surface, is still only 22% of the total energy associated with the drop to a puncture bar. The drop to a puncture bar was found to be acceptable in the calculations performed in Revision 3 of the SARP.

Other components that need to be considered with respect to the 9 m (30 ft) drop are the capsules and the bore plug. SARP Revision 4 does not update the calculations for the loadings on the capsules. However, the increased loadings on the capsules due to the 33% increase in reported capsule weight are acceptable since the calculations presented in the SARP in Appendix 2F, using the originally reported capsule weights, predict margins that are typically a factor of about ten and, with a reduction of 33%, these margins would still be about seven.

SARP Revision 4 discusses the impact of the added bore plug on the drain plug and other components holding the bore plug in place. Maximum impact loads would develop on the plug's restraining components during a side drop. The stresses developed in the restraining components with the mass of the bore plug included are only a few percent of allowable stresses and are therefore acceptable.

For the regulatory 1 m (40 in) drop to a puncture bar, the only significant change in Revision 4 of the SARP is the increase in total package weight. The analysis presented in Appendix 2E and summarized in Section 2.7.2 of the SARP shows no significant problems associated with the drop on a puncture bar. The associated margins are large enough to remain unaffected by the 2.4% weight increase. The drop to a puncture bar would only be significant for the maintenance of containment boundary seals which is not a requirement for Revision 4 of the SARP.

The other hypothetical accident test conditions, namely thermal and immersion, are not affected by the changes introduced in Revision 4 of the SARP.

3. Thermal Evaluation

In Revision 4 of the SARP, a redesigned personnel barrier will provide a minimum distance of 17 cm (6.5 in) between the cask body and accessible package surface. Even though this distance is less than the original spacing, the separation is large in comparison to a thin thermal boundary layer of the order of 1 cm (0.5 in) at the cask surface. Therefore the accessible surface temperature will still remain close to that of the environment temperature. The package will therefore comply with the allowable temperature of 82°C (180°F) specified in 10 CFR 71.43(g) for an exclusive use shipment.

Revision 4 of the SARP also eliminates the need for the cask surface temperature monitoring to assure thermal loading would be less than the 4.0 kW certified. The deletion of this procedure is acceptable since the administrative and procedural requirements in Chapter 7, Section 7.1, assure the thermal decay power will not exceed 4.0 kW. In addition, the staff has calculated the thermal loading for the maximum radioactive loading of $6.5x10^5$ Ci of strontium-90 fluoride to be 3.6 kW and for $8.5x10^5$ Ci of cesium-137 chloride to be 3.0 kW, which is below the maximum 4.0 kW thermal decay power allowed.

3.1 Methods of Analysis and Confirmation

The methods of analysis and confirmation have not been changed in Revision 4 of the SARP.

3.2 Normal and Hypothetical Accident Conditions

The peak temperatures allowed for normal conditions are based on the cask cavity being filled with helium for heat transfer enhancement. The SARP specifies that the cavity be filled with helium before each shipment. Inadvertent loss of the helium will not jeopardize capsule integrity if the transit and wait period does not exceed 30 days. More than 30 days without helium fill may cause excessive internal corrosion of the cesium chloride capsule cladding due to increased temperatures. For the hypothetical accident conditions, the peak temperatures allowed are based on the cask cavity being filled with air because the packaging is not required to remain helium leaktight under accident conditions. The lid bolts, bolt inserts, and threads in the cask body can relax during the hypothetical accident fire since no credit is taken for lid seal performance under hypothetical accident conditions and containment is provided by the Special Form capsules. These conditions have not changed in Revision 4 of the SARP.

3.3 Cavity Internal Pressures

Peak cask cavity internal pressures have not been changed in Revision 4 of the SARP.

4. Containment Evaluation

4.1 Methods of Analysis and Confirmation

The confirmatory review covered the adequacy of the source description; the adequacy of the containment boundary description, specifically the corrosion performance of the Special Form capsule materials and welds; and any supportive information or documentation provided in Revision 4 of the SARP.

The contents are Special Form radioactive cesium chloride or strontium fluoride mixtures that are contained in double walled, all welded capsules. After fabrication, the inner capsules were tested to ensure leak tightness in accordance with ANSI N14.5 or better. The outer capsule closure welds were inspected ultrasonically to ensure weld penetration of at least 55%. The Special Form capsules provide the containment for this package.

4.2 Normal and Hypothetical Accident Conditions

Revision 4 of the SARP has been reviewed to determine that the containment performance of the package complies with requirements of 10 CFR 71.51 under both normal and hypothetical accident conditions of transport. The BUSS cask only provides a confinement boundary for the helium fill gas while the Special Form capsules provide the actual containment. The confinement boundary was modified in Revision 4 of the SARP through the addition of a repair plug welded to the cask body at the upper vent port. The repair was judged adequate by the staff for the confinement of helium.

To determine that the Special Form capsules provide adequate containment, the thermal and stress conditions experienced by the Special Form materials in the packaging must be less severe than the Special Form test conditions of 10 CFR 71.77. The BUSS packaging provides this needed protection except that the capsules, during normal conditions of transport, will be held at an elevated temperature for a much longer time than the 10 minute Special Form elevated temperature test duration but at only 437°C (819°F) instead of the 800°C (1475°F) Special Form test condition. The exposure to temperatures less than 800°C (1475°F) may cause some corrosion of the cesium chloride capsule inner wall. The amount of corrosion, however, is found to be acceptable, being only 0.005 cm (0.002 in) in a 0.24 cm (0.095 in) thick wall for the 30 day transit and wait period allowed.

In addition to the containment provided by the Special Form capsules, the packaging must also confine helium for heat transfer enhancement. Confirmatory analyses of helium leakage have verified that the helium seal design and seal assembly and leakage testing procedures are adequate for confining helium during the maximum allowable 30 day transit and wait period.

5. Shielding Evaluation

5.1 Methods of Analysis and Confirmation

Neither the contents nor the methods of analysis and confirmation have been changed in Revision 4 of the SARP.

5.2 Normal and Hypothetical Accident Conditions

Therefore dose rates under normal conditions of transport and under hypothetical accident conditions shall continue to meet the regulatory requirements.

6. Criticality Evaluation

Since the allowable contents are non-fissile materials, criticality is not a concern.

7. Operating Procedures Evaluation

The changed requirement in the Cask Loading Procedure of Revision 4 of the SARP that the cask cavity be evacuated to 667 Pa (5 torr) for the purpose of verifying the absence of water is acceptable. 667 Pa (5 torr) is much less than the 1.230 kPa (9 torr) for the vapor pressure of water at 10°C (50.0°F), which is the minimum ambient cask cavity temperature allowed during loading.

The operating procedure requirements presented in the SARP will result in the safe operation of the BUSS cask when the requirements are incorporated into the user specific procedures. Procedures are included which assure that the thermal and radioactive loading of the cask will not exceed design limits, and multiple opportunities are present to detect contents overloads. Appropriate radiological protection is assured through the use of timely radiation surveys during both loading and unloading operations.

Review of the physical condition of the packaging and its critical seal surfaces is required prior to each usage. Post-loading leak tests will assure the integrity of the seals prior to shipment. Closure of the cask lid is done in a straightforward manner as is the assembly of the impact limiters onto the cask body and the loading of the assembled cask onto the shipping cradle and is considered acceptable.

8. Acceptance Tests and Maintenance Program Evaluation

Revision 4 of the SARP has changed the Cask Assembly Verification Leakage Test Procedure requirement from a pressure rise test to a mass spectrometer leak test with adequate sensitivity for the lid, and both upper and lower port covers. The requirement that a mass spectrometer leakage test be performed is much more sensitive than the original pressure rise test and this change is therefore found acceptable. The method of connection of the leakage test equipment has also been reviewed and found acceptable.

Fabrication of the parts of the BUSS cask to the required criteria is assured by the application of numerous inspection tests and material verifications. Forging integrity is verified through magnetic and liquid penetrant inspection as well as radiographic and/or ultrasonic techniques. Dimensional checks are indicated in a standard, approved manner. Fabrication of the foam-filled impact limiters is verified by weight/volume measurements before and after filling and by testing of a box sample of the foam batch.

To verify the structural design criteria, a hydrostatic pressure test is required before first use that verifies a 150% pressure capability of the cask body and lid. In addition, helium leak tests are required both prior to first use and periodically thereafter.

Shielding integrity is verified before first use by loading the actual payload and making radiation measurements at the surface and at 2 m (6.5 ft). Thermal testing before first use is also required and is performed with the actual payload, verifying surface temperatures within design predictions. Should shielding or thermal tests exceed the acceptance levels, the acceptable loading will be reduced to levels that will result in proper thermal and radiological criteria.

As a final assurance of confinement integrity, a torque test is required for the lid closure bolts. This test verifies that the preload on the lid closure bolts at the specified torque is correct and assures bolt loadings no greater than those specified in the SARP.

After each use, inspection for "wear and tear" and the usual cleaning of components is performed. Regular maintenance requires the BUSS cask lid and port seals to be replaced after each shipment. A periodic test and inspection schedule is provided to assure that the cask body, impact limiters, trunnions, and other components meet original requirements over the life of the packaging.

9. Quality Assurance Evaluation

The Quality Assurance (QA) Plan requirements presented in the SARP have been reviewed and found to meet the requirements of 10 CFR 71, Subpart H. The QA plan requirements provide sufficient control over all items and quality-affecting activities that are important-to-safety as applied to the design, fabrication, assembly, testing, operations, and maintenance activities of the BUSS cask. The BUSS QA Plan requirements are based on a graded approach for QA requirements as described in 10 CFR 71.101. The graded approach in the QA Plan includes for each item and quality-affecting activity an important-to-safety list (Q-list) that is based on the design function of the item relative to the safety and performance requirements for the complete shipping cask. The Q-list is based on three QA levels with associated definitions for each. The QA level of each important-to-safety item is based on the following criteria and the necessary level of QA requirements is invoked for each item. In addition, the QA Plan requires the user to invoke the same level of QA requirements for any maintenance or repair as the original shipping cask had invoked.

Revision 4 of the SARP has changed the Q-list to represent the as-built configuration. The revised Q-list has been reviewed and found to be acceptable.

1. QA Level 1 (Critical)

   Critical Level 1 items are structures, components, and systems whose failure or malfunction could directly result in an unacceptable condition of shielding.

2. QA Level 2 (Major)

   Major Level 2 items are structures, components, and systems whose failure or malfunction could indirectly result in an unacceptable condition of shielding. An unsafe condition of shielding could result only if the failure or malfunction of a QA Level 2 item occurred in conjunction with the failure or malfunction of other items in the same QA level.

3. QA Level 3 (Minor)

   Minor Level 3 items are structures, components, and systems whose failure or malfunction would not reduce the packaging effectiveness and would not result in an unacceptable condition of shielding regardless of other failures or malfunctions of items in the same QA level.

After determining the applicable QA level for each important-to-safety item, the appropriate level of QA effort for the design, fabrication, assembly, testing, acceptance, operations, and maintenance activities was determined from the 18 QA elements identified in 10 CFR 71, Subpart H and ASME NQA-1 and applied appropriately. The 18 elements identified in the SARP are organization; quality assurance program; design control; procurement document control; instructions, procedures, and drawings; document control; control of purchased material, parts, and components; identification and control of materials, parts and components; control of special processes; inspection control; test control; control of measuring and test equipment; control of handling, shipping, and storage; control of inspection, test and operating status; control of nonconforming materials, parts, or components; corrective action; QA records; and QA audits.

Michael E. Wangler

Michael E. Wangler
Director
Transportation and Packaging
Safety Division, EH-332

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